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Engineer Research and Development Center

Improving Design Communication

Advanced Visualization

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Foreword

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project 4A162720AT23, "Basic Research in Military Construction," Work Unit EC8, "Advanced Visualization."

The work was performed by the Engineering Processes Branch (CF-N), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Blessing F Adeoye. Michael P. Case is Chief, CF-N, and L. Michael Golish is Operations Chief, CF. The technical editor was William J. Wolfe, Information Technology Laboratory. The associated Technical Director was William D. Severinghaus. The Acting Director of CERL is William D. Goran.

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1 Introduction

Background

Architects work in a multidisciplinary design environment that spans engineering and the construction domains. Consequently, architects must communicate themselves to colleagues across disciplines, and they must convey a cohesive visual design (normally a result of collaboration among professionals in several disciplines) to outside customers. This can be a complex task for several reasons.

Designers in different construction areas emphasize different concepts. While they may use similar visual modes (such as lines, text, and graphic symbols) to represent and communicate those differing concepts in complex drawing tasks, they may use those modes in different ways, or to indicate different things. In other words, visual modes may be used ambiguously across disciplines.

Moreover, advances in electronic technology have introduced great diversity in the visual media available. Designers working on parts of the same project may choose between two dimensional (2D) or three dimensional (3D) representations as communication media. These visual media are powerful vehicles for clarifying design ideas to various audiences—both design professionals and outside customers. During a design interaction such as a design meeting, charrette, or presentation to customers, the goal is to use the chosen medium to communicate effectively. To achieve this, designers must understand the different media and how they are used across disciplines.

Most visual modes contain only unstructured graphic entities—lines, text, and graphic symbols. When working on a specific project, individual designers often add structure and meaning to their chosen visual mode. They interpret or assume that certain graphic elements will convey specific design content. Unless there is a standard definition for given graphic elements, the design's audience is likely to interpret the visual modes from its own experience or perspective. The result is that the meaning of any drawing may become unclear or ambiguous.

Drawings need to be precise, accurate, and unambiguous. Architectural drawings are for architects and contractors. These drawings are a means of communication, for those who can understand it. The problem is, of course, that most drawings can be difficult to decipher for many people, especially nondesign cus-

tomers. Although 3D may show an object from up to 10 angles, not all of those angles may appear as realistic representations to non-designers. For instance, to communicate the design of an object as simple as a cube, a 2D, or a 3D alone may not provide sufficient information, but a combination of visual media may provide more information to all disciplines (Figure1).

There is a need to identify and correct inconsistent use of the various visual modes to ensure that consistency is maintained throughout the various visual representations. Such consistency will give designers a better understanding of visual communications, and will lead to improved and innovative solutions that will help overcome problems that stem from visualizing different aspects of the same design project in separate ways.

Objectives

The general objective of this basic research was to explore ways to improve design communications among designers—ultimately to improve the ability of the Corps designers to attract and retain customers and improve design processes. More specifically, the objective of this study was to determine how architects and engineers use visual media to communicate design ideas to their customers and other design team members.

Definitions

The term "Axonometric" refers to a paraline drawing with horizontal planes represented in scale without angular distortion. This representation is sometimes called a plan oblique drawing (Goldman 1997).

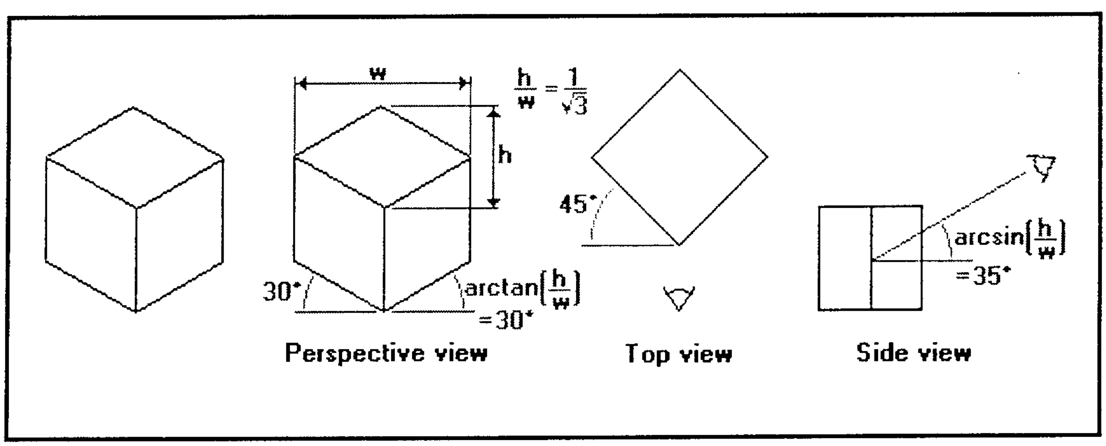

Figure 1. Combinations of different visual media.

A "Plan" or "Floor Plan" is an orthographic projection of the top of a building and its surrounding area. The horizontal slice used to define a plan is taken above and outside the buildings beings represented. A floor plan is similar to a roof plan, but generally covers a larger area (Goldman 1997).

Significance of the Problem

This study is significant to the following audience in the following ways:

1. *Corps Architects*. Architects are mainly concerned with the form and organization of spaces and with the elements that relate to those purposes. Architects need to communicate concepts such as spatial sufficiency, organization, comfort, and aesthetics to customers and other design professionals. This study will reveal important information that will enhance design communication. This information will improve the ability of the Corps to attract and retain customers, and also improve design processes.
2. *Corps Customers*. The Corps of Engineers serves the Department of Defense, other government agencies, State and Local governments, and international customers by providing comprehensive engineering, management, and technical support. The Corps must communicate design effectively to these customers during various stages of the design process. This study addresses issues that will enhance effective design communication to these customers.
3. *Non-Corps Design Professionals*. Generally, the Architect/Engineering domain typifies a multidisciplinary design domain. In the design environment, many disciplines collaborate in different capacities, each with its own concept and interpretation of the object (building) (Rosenman and Gero 1999). Communication can be difficult in such an environment. This study will enhance design collaboration by revealing common design communication roadblocks. A better knowledge and understanding of these roadblocks can help resolve the ambiguities between disciplines that prevent clear communication with design and nondesign customers.

Approach

1. A literature review was done of recent studies of the use of visual media in design communications.
2. Terms related to this study were defined.
3. A research instrument (survey) was designed and the survey was distributed to a selected audience.
4. Survey results were collected and analyzed, conclusions were drawn, and recommendations were made.

Mode of Technology Transfer

It is anticipated that this research will broadly improve collaboration strategies through better visualization in current research efforts involving the areas of Facility Delivery, Life-Cycle Facility Management, and Tele-Engineering. The results of this study will be published via the World Wide Web (WWW) at URL:

http://www.cecer.army.mil/

2 Literature Review

Successful design depends on the effective integration of many design participants. The collective expertise of these participants is required to solve complex synthesis problems. To be practically useful, a design solution must satisfy several criteria. It must be feasible and satisfy the external and internal constraints among individual solution components. The solution should align itself as closely as possible with the defined global objectives of the problem. The design process itself should be efficient with respect to practical constraints on time and resources. Effective design communication is a vital component in realizing these goals. This chapter describes visual communication by exploring the following aspects of multidisciplinary engineering design:

- perspectives on design communication and visualization
- conflicts in design communication
- definition of "visual modes"
- typology of visual modes
- conceptual framework.

Perspectives on Design Communication and Visualization

Visual media, either 2D or 3D, are the primary forms of representation in design. They also are the communication media that have long been used in various design disciplines. During the design process, the architect or engineer must consider many visual modes that may best communicate a complex design. These various possible visual modes will influence the designer's decision in solving problems and communicating to others.

Adeoye, Brucker, and Aviles (1999) investigated different visual modes that influence engineers' decisions in solving problems. They determined significant differences among the effectiveness of various visual modes. The reactions of many users were measured with a limited set of questions that facilitated comparison and statistical aggregation of collected data. Data were gathered, compiled, and statistically analyzed. The results revealed that a combination of visual modes enhance problem analysis and design. The authors recommended further study to investigate the use of visual modes as communication tools to help designers solve design problems across disciplines.

Jones, Brucker, Adeoye, and Woods (2000) proposed improved collaboration strategies through better visualization based on the premise that better collaboration would lead to innovative visualization solutions and problem solving procedures. They presented perspectives on visualization from four points of view: (1) as a language, (2) as a world, (3) as an environment, and (4) as a medium for communication. They explored what is meant by "good visualization" by exploring contextual approaches to visualization. In other words, they argued that good visualization depends on the context of the task, user, and the environment. The "ethics of visualization" involves an appropriate, relevant, and undistorted view of data. What is relevant, however, depends on the user and the tasks. The roles of visualization in collaborative engineering design were presented, emphasizing ethnographic and scenario-based simulation studies, with supplemental interviews and questionnaires. The study established a firm theoretical understanding of the relationship of visualization to the cognitive and collaborative process that occurs in the facility life-cycle process through a presentation of a range of experiments and observation. Jones et. al (2000) focused on the contextual approaches to visualization. This approach was valuable because it provided a theoretical understanding of design communication. However, the study failed to specifically address the visual media that the designers use. This current study will focus on perspectives (2D and 3D) on visualizations as the medium of communication.

Design communication has recently been an issue among various disciplines such as Human Computer Interaction, psychology, sociology, and education. Peng (1994) analyzed three historical cases of cooperative architectural modeling in a collaborative design. In this study, the researcher defined communication as the inter-relationship between common images and distributed design elements. Structuralism and metaphorism were the two generic patterns of communication in collaborative design considered in this study. From the structuralist viewpoint, participants collaborate on modeling complex objects by using common images to build on group primitives as shared generic structures; thus operations play a significant role in coordinating the participants' modeling activities. From the metaphorist viewpoint, the participants approach collaborative design by introducing domain primitives and operations. This study assumes that these elements allow domain expressions to be modeled in individual spaces. Beyond this, the interrelationships between common media indicated in this study, and utilization of the media among the designers is important.

Nielson and Lee (1994) reported the results of an empirical inquiry into how people use communicational codes, natural language, and drawing to attain a shared comprehension of a problem and its solution. They indicated that research in human-computer interaction has neglected communicational codes in favor of task structures. They explored how to characterize the difference between representation or modeling and communication in graphics; how to apply

existing object-oriented theories of knowledge representation to the highly fluid yet knowledge-rich use of pictures; and how to view the differences that could arise between dialogues of this type in different domains. The study concluded that the interpretation of graphics must be seen as strongly dependent on the way graphical expressions were embedded in surrounding discourse. The surrounding discourse may include other designers and nondesign customers.

Also, Rosenman and Gero (1999) indicated that future work would focus on modeling multidisciplinary design teams as a cooperative intelligent agent in a distributed decisionmaking system where communications are essential for achieving project goals. Further research and development was suggested to investigate how each discipline is cognizant of other disciplines' modes of communication and the degree of automation, or the nature of the notification required or possible. This suggestion can reveal conflicts and minimize (or at least reduce) the cost associated with design communication.

Conflicts in Design Communication

Design communications imply transmitting ideas graphically that are conceived and planned abstractly in the mind. Goldman (1997) stated that designers' ideas must be transferred from their minds into some viewable medium for others to see, and that ideas can be developed faster and better with graphics than with words. Forms of design communication include drawings, models, video or screen animation, and written reports. Visual media are essential representations for thinking, problem solving, and communication in the design disciplines, particularly in mechanical and civil engineering, graphic design, and architecture and physical planning fields (Do and Gross 1997). Designers are responsible for communicating to builders or fabricators through visual media. Confusion often arises from the various classifications or typologies of design communication.

As part of the design process, architects and designers draw diagrams and sketches to explore ideas and solutions—especially at the (early) conceptual stage of a design. They must develop the ability to form clear and focused mental images, otherwise they will face extreme difficulty communicating the intent of their designs (Isham 1997). Therefore, the ability to concisely communicate a design idea has at its creative core visualization skills that allow designers to mentally create and manipulate design, and to communicate design effectively. The design of interfaces that support a user's natural cognitive processes and structures depends on an understanding of communication codes as well as task structures. In addressing the visual communications, Smith (1999) conducted an informal survey of top executives of 13 CAD companies regarding the future of designs. The consensus achieved was that 2D design techniques are a major

source of today's design problems, and that they contribute to misinterpretation, which compounds problems in design communication.

Goldman (1997) described four facets of design communications as communication: (1) with oneself, (2) within a design team, (3) with clients and the public, and (4) with contractors. Communication with oneself refers to the fact that designers record ideas as sketches and notes that enable them to look at their own work and to be their own critics so they can improve and modify the designs to attain a desired result. Communication within a design team refers to a collaboration among architects and engineers in which they share ideas. Anumba and Evbuomwan (1994) presented a classification framework for the communication facets implicit in the implementation of concurrent engineering. They identified some communication facets based on a clear identification of distinct groups of people, tools, and project phases across which communication takes place. Conflicts occur not only because of classifications, but also during the design process in various ways. Conflicts happen due to social, technological, scientific, and interdisciplinary dependencies that drive design information during the technical decision and social interaction process in design.

According to Lu, Cai, Burkett, and Udwadia (1999), most of the conflicts in collaborative design are caused by discord among the participants' perspectives. Lu et al. (1999) proposed a methodology for analyzing collaborative design process and conflict using a socio-technical design framework that is based on an acceptance that collaborative engineering design is a human-based, interdisciplinary, and socio-technical activity. They provided a methodology that can identify the interdependencies among design tasks, and that can manipulate the evolution of various design perspectives to facilitate their management. Conflict in design communication also refers to conflict among the information transactions within the design activities. However, Tweed (1999) explored the development of perceptions and interpretation of architectural information. He recognized that research efforts within computer-aided architectural design to develop 3D modeling, photorealistic rendering, and virtual reality are driven by the difficulty nonarchitects have in understanding the conventional projections of plan, section, and elevation. He indicated that research at Queen's University of Belfast supports the view that the availability of different interpretations at the micro-perceptual level depends heavily on the sedimented associations of different subjects (i.e., on macro-perceptual experience). These studies indicated that architects develop the ability to see 3D shapes as they progress through their education and career, and that 2D shapes often became inaccessible to them, although they are readily seen by nonarchitects.

Solutions to conflicts in design communication may be addressed in a general manner that focuses on the design process itself or in a specific manner that focuses on the visual means of design. To address the design conflict, Jeng and

Eastman (1999) developed an electronic environment for effective design process management that supports design concurrency and collaboration. They reviewed current capabilities in data base transactions to support CAD/CAM and proposed a new architecture to support missing capabilities. Anumba and Evbuomwan (1999) suggested the use of a central repository of project information with appropriate mechanisms for consistency checking. These mechanisms will maintain the semantic integrity of the project information being communicated whatever the facet, chronology, location, mode, form, or medium of communication.

Definition of Visual Modes

In this study, a visual mode (synonymous to a graphic mode) is defined as a representation of an object on a 2D surface, such as a graph, diagram, drawing, or chart. To understand the use of the term "visual modes," it is important to examine the typology of visual modes.

Typology of Visual Modes

Lohse, Biolsi, and Walker (1994) developed a classification from similarity measures for 60 visual representations. There are 11 major clusters of representations: graphs, tables, graphical tables, cartograms, time charts, networks, structure diagrams, process diagrams, maps, icons, and pictures. They concluded that a graphic could express either continuous or discrete information, and that some visual representations were more efficient than others for conveying information. They also established a taxonomic structure of graphic items using the Classification and Regression Trees (CART) methodology to construct a binary classification tree. Items are classified by running them down the tree and sending them right or left at each node depending on whether or not they exceed the threshold value for the corresponding splitting variable at that node. By structuring this domain of inquiry at a high level, we can begin to understand how different types of visualizations communicate knowledge.

Jones et al. (2000) also presented a multi-leveled approach to theorizing about visualization in the context of various cognitive tasks related to design. They considered design as a collaborative process shared between participants of differing backgrounds, skills, and agendas. They characterized design practice on levels such as those shown in Table 1. Besides the typology of visual mode, the conceptual framework can also provide further understanding of various visual media.

Table 1. Hierarchy of design practiced levels.

Abstraction Hierarchy Level	Pre-Design Elements
Purposes/constraints	Establish relationship between user, owner, and designer. Establish common vision of design intention
Abstract functions/ priority measures	Health, safety, and welfare Spatial, thermal, air quality, acoustical, visual, building integrity, style, cost-effectiveness, timeliness, and regulatory constraints
General functions	Determine building requirements, determine budget, determine timeline
Activities	Activity analysis, permits/zoning/code analysis, physical space analysis, spatial layout, facility survey, and site survey
Material form/ tools	Architectural programming document, MDS design guides, standard designs preliminary budget, preliminary schedule, checklists drawings, and sketches

Conceptual Framework

The conceptual framework used is intended to be an heuristic model only, providing some guidance for the researcher and the readers in conceptualizing the relationships between visual media used in this study. It is not the intent of this study to test this particular framework. Jones et al. (2000) considered design as a collaborative process shared between participants of differing backgrounds, skills, and agendas. They presented several abstraction hierarchies. Other researchers Rasmussen, Pejtersen, and Goodstein (1994) developed a similar, but broad, abstraction hierarchy. One particular abstraction hierarchy that characterized design-practiced levels is:

- *Purposes.* The purpose of the visual mode is to communicate a concept or idea expressed in a design.
- *Functions.* The media's purpose is to communicate how designs function as well. Every medium serves a specific purpose.
- *Activities.* Different media can be used to explain different activities.
- *Material Form / Tools.* Material used may be generated by a CAD program or by pencil and paper.

This abstraction hierarchy established a link between various levels. It shows different phases of communication during the predesign phase of a design. However, the hierarchy leaves a question unanswered, "How can we improve visual communications among designers?" This current study explores the visual media used in design communication regardless of the design phase. Awareness and understanding of these visual media will help to address the question of how to reduce the confusion that results from failure in design communication. According to this abstraction hierarchy level, there must be a specific purpose for a chosen medium and specific function.

Designers need to communicate their ideas to others. According to the literature studies found in this review, these ideas can be confusing, vague, provisional, and may involve a mixture of degrees of detail and levels of abstraction. Expressing their ideas clearly and unambiguously is a challenge for designers, especially when communicating with nondesigner customers. Clear communication is also a problem for members of design teams who may represent different disciplines. Visual modes, if not chosen carefully, can be both tools and sources of confusion when used to convey graphical messages. This study attempts to address how to improve design communication.

3 Research Design

Description

This study was designed as a quantitative inquiry. It is exploratory in nature and used a survey methodology. Because design is an ongoing process that may last several months, this study used 2D and 3D drawings to elicit information from participants. It was thought that analysis of the data collected from this survey would help the researchers to discover common visual modes to address the research questions, and accept or reject the hypothesis for this study. The survey instrument was accompanied with two sets of drawings (2D and 3D). Participants were instructed how to access the data collection instrument, which was located at http://www.cecer.army.mil/pisurvey/visualstudy/cerl.cfm. (This site may not be available after FY00).

Research Question

In its most general form, the research question that this study was meant to answer was: "How can we improve visual communications among designers?"

Hypothesis

This study was designed to explore alternative hypotheses:

H_0: *Design professionals use different visual modes to communicate design.*

to be tested against:

H_A: *Design professionals use the same visual modes to communicate design.*

Pilot Test

A survey questionnaire was given to five trainees at the Omaha CAD training center: one CADD draftsman, one landscape architect, and three architects. Most of the trainees were familiar with AutoCAD and MicroStation, but none

was knowledgeable about ArchiCAD. The trainees were scheduled to start working on a project entitled "The Recreation Center" on the last day of the training. A survey questionnaire (pretest) was given to them at the beginning of the training and the same questionnaire (posttest) was given to them after the completion of their design project. Appendix A gives more detail of this pilot test.

Data Collection

The survey questionnaire was posted to a website and also e-mailed to alt.architecture newsgroup (Newsgroup for building design, construction, and planning), alt.architecture.alternative (Non traditional building design), and the U.S. Army Corps of Engineers' architects. Purposive sampling was used in selecting the participants for this study. These participants were selected because of their knowledge and experience in the subject matter. Participants were selected specifically to facilitate participation from different geographic locations.

4 Data Analysis

This chapter presents the data as reported by the participants.

The survey questionnaire was posted to a website and also e-mailed to alt.architecture newsgroup (Newsgroup for building design, construction, and planning), alt.architecture.alternative (Non traditional building design), and the U.S. Army Corps of Engineers' architects. Sixty-nine architects/designers participated in this study. The participants include a good cross-section of Corps architects. A unique characteristic of the participants is the diversity in grade levels, years of experience, and geographical locations. Forty-five out of the 69 participants (about 65 percent) were Corps of Engineer's architects/designers; 24 architects were from the private practice. The years of experience ranged from 2 to 32 years. Also, the grades of the Corps architects that participated are from GS 11 to GS 15. Figures 2 to 10 show the frequency distribution of participants' responses.

Research Question 1–Text

What is/are the best visual media to explain a design concept to a customer who is not familiar with architectural conventions?

Figure 2 shows that about 67 percent of the participants indicated that both 2D and 3D media best explain a design to a nondesign customer while about 28 percent indicated only 3D. Only 3 percent indicated 2D. About 8 percent were neutral.

Research Question 1–Comments

(The comments are not interpretations but direct comments from the participants).

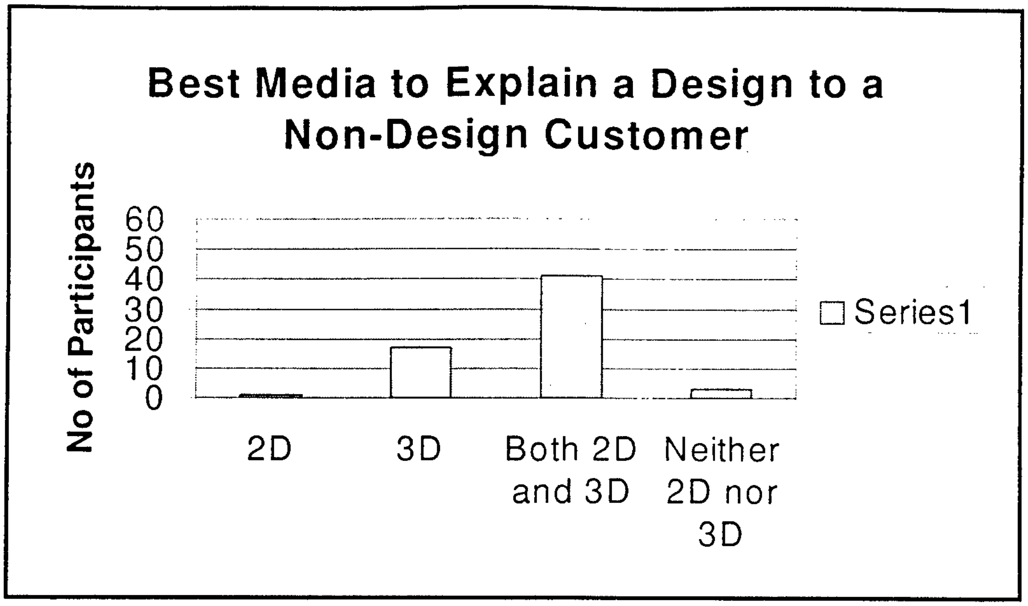

Figure 2. Results from research question 1.

2D

2D media help the customer understand the logic and relationships of rooms within a building or buildings as they relate to other buildings on a site plan, while 3D help the customer to visualize the detailed design of a particular room. (Six participants indicated this.)

Sometimes 3D takes too long to convey a simple concept; 3D is good for more complex concepts.

3D

In 3D, clients can visualize the circulation, elevation, and the volume, but often cannot visualize what the 2D is like in terms of volumes—ceiling lines, casework.

Floor plans and elevations don't describe the concept behind a design. Depth gives a bit more understanding. Actually, this has to be combined with a verbal and written description.

A customer not familiar with architectural conventions has a hard time visualizing a set of construction drawings. A perspective rendering and/or 3D CADD drawing provides the customer with a visual expectation that he is able to understand.

3D media provide the clearest representation of the actual design for the non-designer. (Four participants indicated this.)

3D presents depth whereas 2D does not. Untrained eyes can probably better understand spaces when presented in 3D.

Both 2D and 3D

Customers see concepts better in 3D; 2D helps to solidify what they see in 3D. (Six participants indicated this.)

Most clients have difficulty understanding two-dimensional space.

2D drawings typically are used to explain interior space, or areas of little complexity and 3D for complex solutions that are difficult to visualize.

Most of our direct customers are knowledgeable in architectural drawings in some degree. Only when a meeting includes "green suiters" do we use 3D to "sell our product."

Too much 3D may confuse the clients while too much 2D will not represent ideas very well. To present ideas thoroughly, a combination of 2D and 3D will be preferable.

Varies depending on what you are trying to explain or the complexity of the design. Generally a 2D and 3D presentation will be most informative.

The use of plans combined with a rendering helps the layperson see what the building really could look like. Using the 2D convention helps to understand relationships between plans, elevations, etc.

2D provide relatively simple explanations of relationships between spaces. It provides easy line-to-line measuring for difficult information. 3D greatly helps people visualize things that they have trouble imagining.

2D is fast for plan view. 3D helps with unusual interior configurations and also it sells exterior concepts easily. It may actually cause the client to want to see more details. (This causes delays and adds to costs).

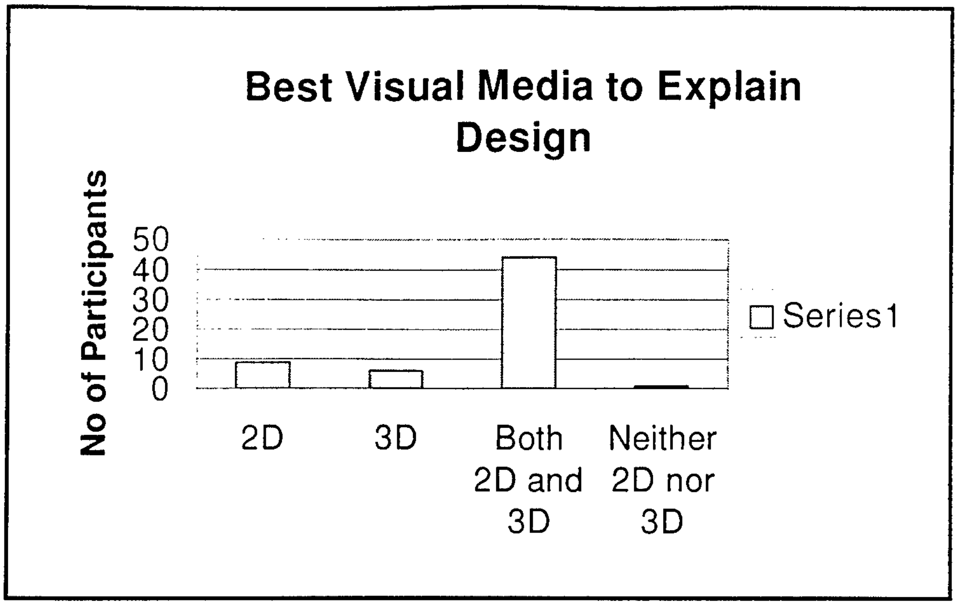

Figure 3. Results from research question 2.

Research Question 2–Text

What is/are the best visual media to explain a design concept to another architect?

Figure 3 shows that about 90 percent of the participants indicated that both 2D and 3D media are the best media to explain a design to another architect while about 20 percent indicated only 2D. Only 10 percent indicated 3D and about 3 percent are neutral.

Research Question 2–Comments

2D

Most architects can visualize the 2D so it is often quicker in concept to use 2D. (Three participants indicated this.)

Saves time. It is faster than trying to create/generate a 3D drawing.

3D

3D is a better approach for illustrating a design concept, since the architect has a good understanding of spatial arrangements. Then 2D information can be provided to close the loop on technical issues in the design process.

3D offers the greatest communication and visualization of the design concept or proposal and allows for easy interpretation, thus relying less on the other persons understanding of explained imaginary 3-dimensional space.

Most of the time 2D is fine; however nothing communicates a complex concept as quickly as 3D.

Both 2D and 3D

2D can explain a concept to an Architect very well. When combined with 3D, it speeds up the process. (Six participants indicated this.)

It really depends on the complexity of the concept/detail/whatever; both are necessary to fully understand a design. (Four participants indicated this.)

Most architects can project the space from 2D drawings, but there are times when a 3D such as perspective drawing or model (virtual or otherwise) helps convey certain points. Sometimes specific ideas can be conveyed more easily and directly in a simple 2D drawing; simple concepts can get lost in complex 3D representations.

Because Architects are familiar with the concept of plans, sections, and elevations they have been communicating with each other with 2D more than 3D. On fine details where it may be hard to visualize, they sometimes communicate to each other using 3D sketches.

Both 2D and 3D are needed tools in developing and presenting ideas. It does not matter if you are talking to a client with a limited knowledge base or an architect with 30 years of design experience. They are both excellent means in developing and expressing solutions to a design problem.

The more information you can show, the easier it is to sell ideas to anyone, even to fellow professionals.

Thumbnail perspectives are probably the quickest to explain a concept; but sketches of any sort regardless of 2D or 3D can also suffice. (Three participants indicated this.)

Architects currently practicing are used to seeing a design in 2D and can understand it and its associated dimensions, but 3D allows the use of color, shades, and shadows.

While there is an understood vocabulary amongst architects where a particular word(s) can convey an entire concept (ex: Beaux Arts configuration), we still generally think in both 2D for planning and 3D for form. In order to fully explain the concept, one must review not only the product as designed, but also the thought process of the design.

It is very important for a designer to give an over-all design description to another designer in various formats.

Research Questions 3—Text

In what situation would you prefer 2D media to express your design? Please explain. (Table 2 lists the responses to this question.)

Table 2. Responses to research question 3.

Themes	No. of Responses
Schematic design, programming stage, preliminary decision making (area calculation)	8
Working drawings	7
Cost effectiveness and time	6
When the layout of spaces or space planning is the primary issue	2
Technical issues and details	9
Size of the project (large scale project); simplicity	2
When only 2D makes sense (road or parking lot, sidewalk, site)	6
In explaining relationships	12
Miscellaneous responses	
Narratives, fact & figures, bullets of significant issues or points. Comparisons of data like DD1391 scope with design concept.	
2D is preferable on situation where the other area of building or project does not play an important role in the overall design.	
2D keep the quantity of information being presented under control. That means less confusion and quicker understanding	

Research Question 4—Text

What visual media would you use to explain a fire rating to a mechanical engineer?

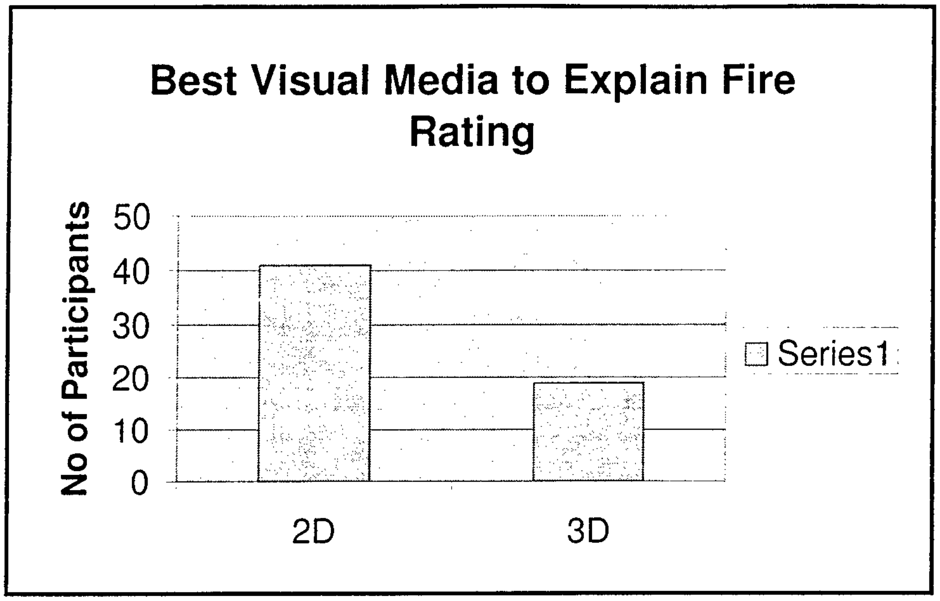

Figure 4. Responses to research question 5.

Figure 4 shows that about 90 percent of the participants indicated that 2D media are visual media they would use to explain a fire rating to a mechanical engineer while about 38 percent indicated 3D.

Research Question 4—Comments

2D

2D is easier to mark up.

Allows a more detailed discussion on fire rating and fire-rated materials being used. (Three participants indicated this.)

Mechanical engineers do not respond well to 3D images.

In 2D you can see what is to be protected and what it is cutting through. (Three participants indicated this.)

Fire rating materials usually pertain to walls in plan view; thus the plan view is best.

3D best describes materials. However, the mechanical engineer needs to know how to handle penetrations through fire-rated construction and the "3D" visual of an exterior concrete wall does not give enough detail.

3D

The massing and materials can be better explained to the engineer. (Three participants indicated this.)

Both 2D and 3D

With fire rating both inside and outside, conditions need to be viewed at once.

Other Comments

A picture of the system (but not the building) would be most effective. For fire compartments or locations of fire-rated assemblies, then the plan view would work better.

We regularly send photographs, attached to an e-mail message, back and forth with customers. I don't necessarily consider photography to be 3D communication.

Research Question 5–Text

> *If you can only choose one between 2D and 3D, which visual media would you use to explain an alarm/security system to electrical engineers?*

Figure 5 shows that about 83 percent of the participants indicated that 2D media are the best visual media they would use to explain an alarm/security system to electrical engineers while about 25 percent indicated 3D.

Research Question 5–Comments

2D

2D is easier to mark up. (Three participants indicated this.)

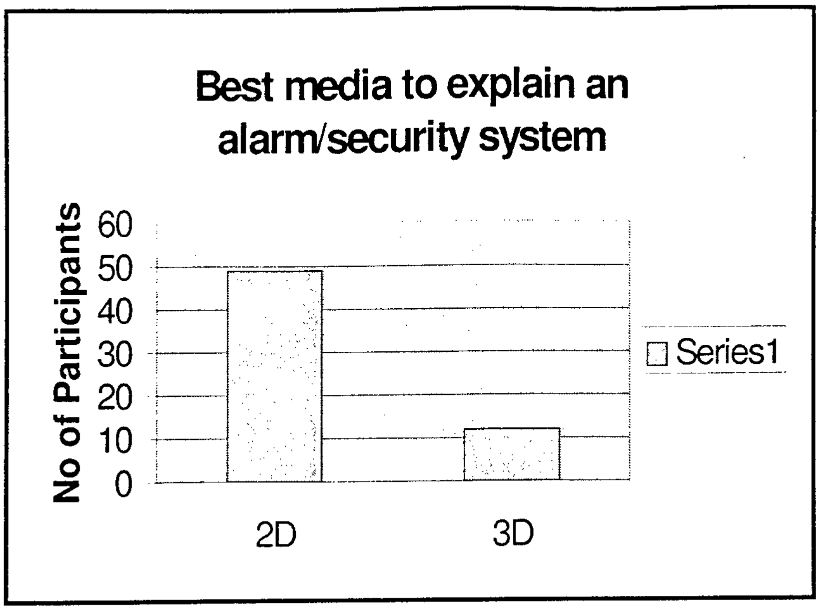

Figure 5. Responses to research question 5.

The floor plan allows a more detailed discussion in the planning stage. Its location and relationship to the building is better illustrated with 2D media. (Three participants indicated this.)

The plan shows more details.

The plan shows location and wiring of the alarm/security system.

2D is cleaner and you can see the different spaces.

The volumetric study overpowers the intent and lacks the required information - and an electrical engineer would not be impressed.

The engineer just wants the facts.

3D

A system is perhaps best illustrated with a picture or an exploded view.

3D makes more sense; after a specific design concept, the electrical engineer can incorporate comments into his/her design.

I might use a photograph to indicate conditions of potential intrusion and duress.

I may want the electrical engineer to explain this to me.

Research Question 6–Text

What issues in a design communication between architects and engineers would you suggest we address?

Research Question 6–Comments

How do you get engineers to actually do or listen to what you are telling them?

The biggest issue for communication between disciplines is always coordination between the various drawings and discipline. (Fifteen participants indicated this.)

Timely disbursement of project.

Start communications early in the project.

Who is in charge?

Visualization of space. Three-dimensional design.

I don't think the big issue is 2D vs. 3D; I think the big issue is the actual communication between designers throughout the life of the project.

Establishment of full working teams that are cross-trained to understand the needs of other designers.

The best visual presentations I have seen in the last 5 years have included more than just one sense; the use of sound, and possibly touchable 3-dimensional models, have been very helpful in capturing the full design content and intent.

It is extremely hard for most engineers to "visualize" things in 3D. Engineers should be more aware of architectural terms and principles. Engineers do not see a need for 3D design. Investigate what tools would motivate them into using 3D.

Design communication is essential for architects and engineers to avoid conflicts during construction. For example: Will the mechanical air-conditioning ducts clear the structural beams? Are the mechanical diffusers located at the same location as the lighting fixtures? (Three participants indicated this.) How does

an architect explain a ceiling concept to an electrical engineer so that his lighting blends?

Direct communication skills, listening skills, people skills, and the ability to think on your feet to solve and probe for questions.

The importance of aesthetics in an architectural design. Engineers were educated in the basics of building sciences, not in the art of design.

Drawing to scale seems to be a problem for engineers.

Issues such as required volume, flexibility (or inflexibility of equipment), accessibility requirements, maintenance requirements, life-cycle expectancy and replaceability of equipment, components, and materials are some of the issues that should be communicated at the earliest possible point in the design.

The most critical element the design team has is maintaining a line of constant communication. With virtual teams that can span continents, we need the ability to be in constant communications with each member of the team. This can be partially accomplished by having the design elements electronically stored in one location and the floor plans and other critical drawings referenced and cross-referenced to each other. The other critical part of this communication should be accomplished face to face (video conferencing over the Internet) with the ability to discuss plans and specifications—while referring to drawings that both parties can see.

A mini-charrette between the designers at the start of the project is important. All too often the design is compartmentalized. It is an assembly line design process: floor plan by architect is passed to civil engineer, mechanical engineer, etc. There is no feedback loop and no one knows what the finished product is supposed to look like or conform to.

To reduce misunderstandings between architects and the engineers, architects should provide some images to engineers of what they are designing. Only then would both sides be able to discuss more of their impressions of the finished product rather than more technical stuff.

The use of CADD to overlay plans and check for conflicts between disciplines should be emphasized. Also, showing engineers in the field what some of their equipment looks like in a building would be a plus.

Architects need to educate engineers. For instance, mechanical engineers need help visualizing how ducts maneuver in 3D. Electrical engineers need help understanding the relationship between the light fixtures and the glazed openings.

Also, Structural engineers need to understand needs for clearances and connectivity of finish systems and their detailing requirements.

Research Question 7–Text

In what situation would you prefer 3D media to express your design? Please explain.

Research Question7–Comments

When speaking with clients in terms of what the project will actually "look like."

When determining if systems are in conflict. (Nine participants indicated this.)

Only when complex geometry necessitates 3D for understanding relationships.

Schematic, conceptual phases, and final presentations. The former because this is where the project takes "shape." The latter because this is where it feels like the project is a reality to the customer.

For public relations or general presentation.

Where the features of a 3D space were the most significant aspect of the design proposal.

3D in early design work and 2D for design resolution.

To "sell" a project to a client or persons who are not knowledgeable in architecture/engineering. (Six participants indicated this.)

Complicated facades and interior volume are best defined in 3D.

Almost all-vertical construction.

When dealing with complex spaces and engineering systems.

Concept, 10 percent design, design charettes, and the early phases. Also design award presentations, briefings, or when it helps the contractor construct.

When 3D would help visually describe the volumetric impact of such spaces as an atrium open to the third floor of an interior space. It would help visualize the interconnection between structural, mechanical, and electrical systems.

At the conceptual phase of design and at the completion of design. (Three participants indicated this.)

When you want your overall architectural theme to be approved or to convey that quick snapshot that can be illustrated by thumbnail sketches.

Maximum utilization while taking into account equipment limitations and time.

For interior layout, also as a tool to look for conflicting conditions that may be more easily missed in 2D; during reviews with users, to explain spatial relationships and with the building site; for rendering; during construction to visualize the "vertical" structure for the contractor and subcontractors, for the steel and HVAC subs especially.

Research Question 8–Text

In what situation would you prefer tabular media (spreadsheet) to express your design?

(Table 3 lists the responses to this question.)

Table 3. Responses to research question 8.

Common Themes	No. of respondents
Scheduling	8
Programming phase	3
Cost analysis/budgeting/estimate	15
Dealing with numbers/calculation	3
Analyzing options	5

Research Question 8–Comments

When showing overlapping systems; it can be helpful to go from layer to layer with a tabular medium.

Space allocation, circulation percentages, and fire protection calculations.

Tabular media supports the design process/communication—floor areas, code checks, decision matrices, quality checks, etc.

To explain tabulation of floor areas and/or to explain pros and cons of material comparison for selection.

Description of the functional layout of a building. Showing circulation patterns as they flow through a design. Location of service areas both interior and exterior. Description of life safety and fire protection attributes of a building.

For programmatic relationships and large quantities of spaces.

When dealing with costs, life-cycles and comparisons, as well as scheduling, tabular data can be used most effectively.

Design review meetings and briefings.

In developing scope, comparing data, or illustrating various uses in a building.

For comparisons: existing vs. proposed; DD1391 SOW vs. actual design Cost estimates VE proposals Life-cycle costs.

Research Question 9–Text

In selecting basic structural systems, which of the visual media below would help you communicate design to a structural engineer?

Figure 6 shows that about 90 percent of the participants indicated that 3D media are the best media that would help them communicate design to structural engineers while about 30 percent indicated 2D.

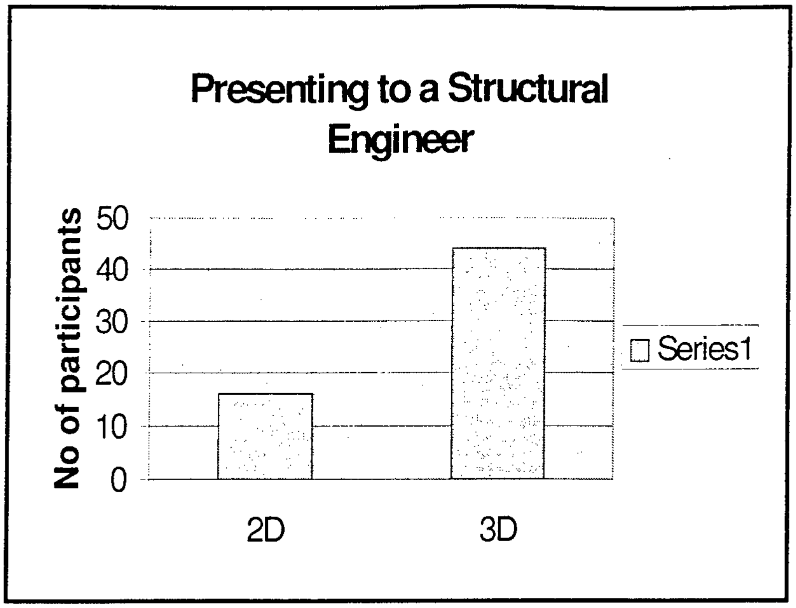

Figure 6. Responses to research question 9.

Research Question 9—Comments

2D

The "3D" in this case does not show all the aspects of a structural design. Where are the shear walls located in the "3D"? What size are the interior columns? "3D" in this case does not depict enough information. Another one is the size and shape of penetrations through walls and floors.

2D is probably better to explain or discuss structural detailing.

Many of our structural engineers don't use CADD; we would have to provide them 2D drawings of the design.

Structural engineer calculates their structural design based more on the weight distribution of the building. Unless the design comes in a unique form that cannot be represented or understood in a simple 2D plan, a 3D modeling is not necessary.

3D

The structure is much more easily understood in the 3D graphic. (Five participants indicated this.)

Structural engineers think in 3D almost as much as Architects. (Four participants indicated this.)

3D perspective illustrates much more effectively the proposed structural system. (Three participants indicated this.)

This is a case in which 3D might be an advantage. Multidirectional structural systems are difficult to visualize.

3D illustrates the design for myself and 2D plan is understood clearly by a structural engineer.

The 3D media shows a lot of structural information all at once while floor plan needs additional drawings to determine structural design.

3D provides an image that minimizes the guess work by the structural engineer.

To communicate a structural theory, the 3D media would show the most information with the least effort as opposed to looking at many 2D drawings.

Both 2D and 3D

After the structural system is decided upon, the expression of that system is best discussed in 3D.

Need detailed drawing to get down to cases on a myriad situation.

Research Question 10–Text

> *What visual media would you choose to present your design to landscape architects to discuss site-planning issues?*

Figure 7 shows that about 90 percent of the participants indicated that 3D media are the best media that would help them communicate design to landscape architects while about 30 percent indicated 2D.

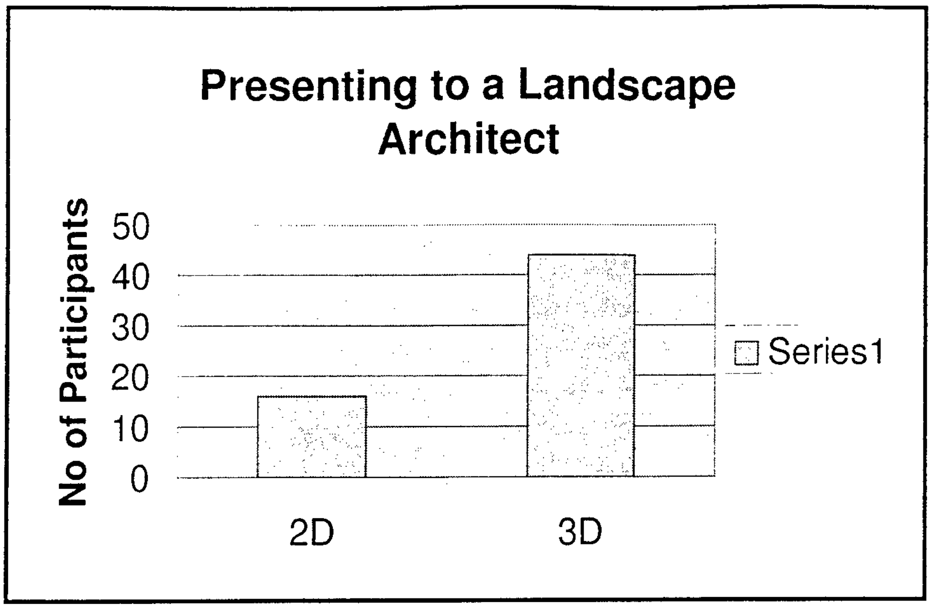

Figure 7. Responses to research question 10.

Research Question 10—Comments

2D

2D plan would be used to illustrate adjacencies, zoning issues, etc., but the 3D view would also be used to illustrate contextual information, for instance.

2D is less structured for planning purposes. Zoning, existing conditions, location of utility services, etc., can be graphically shown.

2D shows utilities and grading features that it would take several views of 3D to show, and the solid above doesn't show these items.

2D plan permits many overlapping issues to be diagrammed and discussed in a constructive manner; interrelationships are revealed.

3D

It may be a lot better to discuss landscaping issues with a landscape architect in 3D because the selection of the tree will be dependent on the adjacent structure, roads, surrounding areas, and/or architectural theme or patterns.

Both 2D and 3D

I don't think landscape architects would be able to "visualize" as well from an abstract 2D view as other design professions.

Presenting a design idea to a landscape architect, photos will be more appropriate. The photographic image communicates many things at once ... scale (somewhat), land use, traffic patterns, building mass, materials, context, etc.

While height and massing are extremely important factors in landscaping, site planning can be, most of the time, discussed from 2D.

Most landscape architects are trained to think in both 2D and 3D. Therefore, the communication is not hampered by the lack of a 3D image but beginning the conversation with a plan may generate new ideas without the constriction.

Research Question 11–Text

What visual media would you choose to present your design to civil engineers to discuss civil engineering issues?

Figure 8 shows that about 82 percent of the participants indicated that 2D media are the best media that would help them communicate design to civil engineers while about 30 percent indicated 3D.

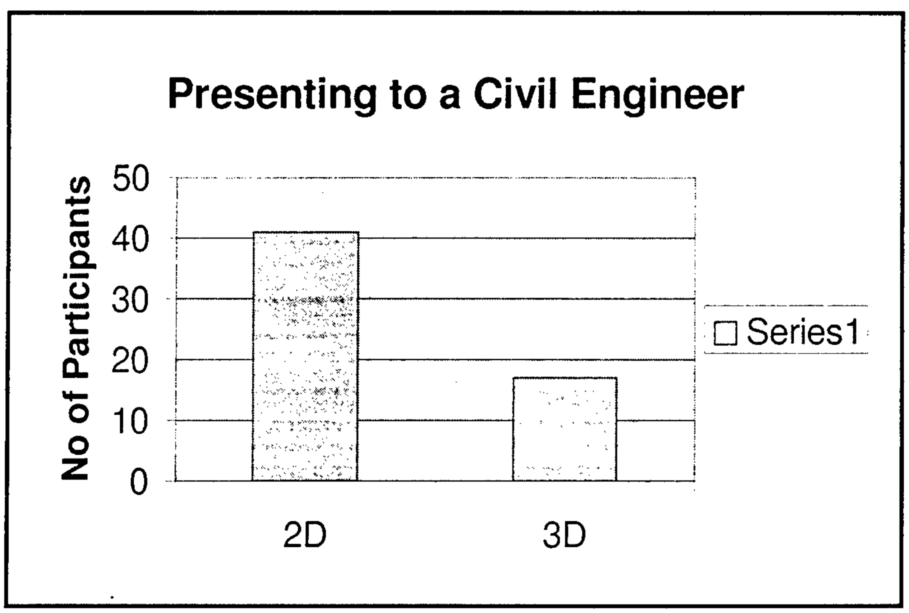

Figure 8. Responses to research question 11.

Research Question 11–Comments

2D

The realistic 3D view is not as important as contours, scalable site features, etc. (There would be no way for them to calculate storm water management, for example, from a 3D view.)

Traffic, drainage, elevation, utilities, and other site-related issues are best discussed and addressed from site plans.

Civil engineers seem to think primarily in 2D. Rarely do their design or design development drawings include 3D drawings or sketches.

3D

There are merits to 3D in discussing site issues.

Both 2D and 3D

Actually both would be good in this situation.

Civil engineers within the context of most facility projects are most concerned with 2D-plan information from an infrastructure standpoint. However, the 3D view would help in communication of the design concept.

Most of our discussions with the Civil Engineers have been using 2D plans. Although we have been effective in using 2D in our past discussions with civil engineers, the use of 3D would probably help us better communicate the architect's site planning ideas across to the engineer.

Most site planning is done in 2D with 3D sections, however; any difficult or complex site issue would be best discussed with both 2D and 3D.

Understanding utilities is necessary to the design of a site. 3D is a good tool for grading and building placement.

Depends on what your try to present. Both are appropriate in certain circumstances.

I have had times when cut and fill issues came up due to misread contour lines.

Research Question 11–General Comments

I think we should make a conscious effort to move to 3D. We have the technology, and that's the world we live in (in most cases).

I think that both 2D and 3D media have their pros and cons. In most cases, the media that we select is based on the designers familiarity with 3D, and more so the length of time and funds that we have to prepare the media.

Very revealing. Thanks!

The settings or situations needed to be better described. Different media might be used if it were to portray existing conditions, conceptual thoughts, review situations, etc.

Initial design concepts are best developed and expressed using 3D schemes. As the design develops to the more mundane/commonplace details in plan/elevation, sections are more appropriate. A spreadsheet has a place in the process in that it can be used to keep track of quantities. It is used later in the construction process but is no less part of it. The best way to work is to take advantage of all three. Omitting any part of it decreases the overall effort.

The cost consciousness and the need to better communicate between design team members and the nontechnical members of building team (customers and management), dictates the use of a more automated methodology of delivering in 3D.

This is all wonderful, but unless the software and training are provided, we will continue to provide the same products. The issues of 2D vs. 3D have created competition between Corps designers and AE firms. We (Corps) do not have 3D capability the way we should.

I hope you're asking the engineers similar questions since communication is a 2-way street. You might also include interior design. Also, consider making a distinction between two client types; the one who uses the facility and the one who pays for it. In government work, it is very common for those to be separate roles.

5 Research Findings and Discussions

The major research was how to improve visual communications among designers by explaining the following alternative hypotheses:

> H_0: *Design professionals use different visual modes to communicate design.*

to be tested against the alternative:

> H_A: *Design professionals use the same visual modes to communicate design.*

For the research question in this study, the researcher focused on the participants input for improving design communication. Common themes surfaced. Many of the participants indicated that 2D media helped the customers understand the logic and relationships in a design. Many also indicated that 3D media provide the clearest representation of the actual design for the nondesigner. However, when designers communicate to other designers, they switch back and forth from various media. Some participants indicated that both 2D and 3D are needed tools in developing and presenting ideas because they are both excellent means in developing and expressing solutions to a design problem. Therefore to answer the research question, the study found that a combination of various media would improve design communication.

Design involved many people, many disciplines, and many visual tools. Based on lack of agreement on a particular medium among designers, it is impossible to come up with a solution to design communication problems. The information provided in this section is should not be considered the only solutions. These are common themes revealed from the participants as some of the ways to improve design communication:

1. A combination of visual media is better than one type of visual mode.
2. Architects cannot assume that other designers and clients understand the visual mode they are using in communication. They need to be aware of the best visual mode for a particular discipline or customer.
3. Coordination between various disciplines and the media used is very important. Verbal communication must be added to media communication where possible.
4. For the architect/engineering community as a whole, engineers need to be educated in design communications. Also, architects need skills in understanding

the limitations and ramifications of certain engineering systems to avoid as many conflicts as possible during the design communications.

5. The most critical element the design team has is maintaining a line of constant communication. With virtual teams that can span continents, there is a need for constant communications with each member of the team. This can be partially accomplished by having the design elements electronically stored in one location and the floor plans and other critical drawings reference and cross-referenced to each other. The other critical part of this communication should be accomplished face to face (video conferencing over the internet) with the ability to discuss plans and specifications while referring to drawings that both parties can see.
6. Architects need to understand each disciplines areas of concern and how they need to be helped. For instance, mechanical engineers need help visualizing 3D situations for their ducts to maneuver. Electrical engineers need help understanding the relationship between the light fixtures and the glazed openings. Structural engineers need to understand the critical clearances and connectivity of finish systems and their detailing requirements.

Also, to accept or reject the hypotheses explored in this study, the researchers looked at the participants' responses. Sixty-seven percent of the participants indicated that both 2D and 3D, and 28 percent indicated that only 3D was preferable as the media to communicate design to a nondesign customer. Only about 2 percent of the respondents preferred 2D. This finding is relevant to the literature (Tweed 1999) that recognized that nonarchitects have difficulty in understanding 2D—especially the conventional projections of plan, section, and elevation. Also, Smith (1999) concluded in his study that 2D design techniques are a major source of today's design problems, and that they contribute to misinterpretation, which causes a big problem in design communication.

In general, the audience, the situation, the message, and availability of media contribute to the choice of visual media for communication. For instance, 67 percent preferred both 2D and 3D when communicating to a nondesign customer; 90 percent preferred both 2D and 3D when communicating design to another designer; 82 percent preferred 2D to explain fire rating; 83 percent preferred 2D to communicate to electrical engineers; and 90 percent preferred 3D to communicate to structural engineers.

Based on the findings and various comments made by the designers, this study accepts the hypothesis that design professionals use different visual modes to communicate design. It is not the intent of this study to promote the use of either 2D or 3D media, but to explore how to improve design communication through the media to designers. The acceptance of this hypothesis is in agreement with the following researchers who also concluded that designers use different visual modes to communicate design (Adeoye, Brucker, and Aviles 1999; Do and Gross 1997; Goldman 1997; Rosenman and Gero 1999).

6 Conclusion and Recommendations for Further Studies

Conclusion

There are very different cultures among the different professions and disciplines involved in design and construction (architects vs. engineers vs. draftsmen vs. customers). These groups will use sketches, diagrams, and drawings in different ways. Although architects are likely to use and understand visual tools at all stages of design and construction, engineers are not likely to use or have expert knowledge about all the visual media used by architects. Nevertheless, it is critical that design communication between these groups be effective.

Designers are responsible to communicate to builders, fabricators, clients, and other designers through visual media. Often, there are confusions because of discord among the participants' perspectives (Lu et al. 1999). Also, lack of understanding of the customers, assumptions that the customers will understand the media used, various classification or typology of design communication, and lack of the right media to use. However, designers must develop the ability to form clear and focused mental images or they will face extreme difficulty communicating the intent of their designs.

Recommendations for Further Studies

Communication is a 2-way street. This study explored the visual media that the architects use to communicate design. Based on the findings and comments from the participants, this study recommends the following for further study:

> *How can visual communications among engineers and architects be improved?*

This hypothesis can be tested:

> H_0: *Engineers (electrical, structural, civil, etc.) use different visual modes to communicate design.*

against the alternative:

> H_A: *Engineers (electrical, structural, civil, etc.) use the same visual modes to communicate design.*

This study can also be replicated using a qualitative paradigm, specifically, a case study. The case study methodology will address the in-depth descriptive of how and why the tested hypothesis is true or false. The case study may also investigate the impacts of using various visual media. According to Bogdan and Biklen (1992), a case study can be used to describe and characterize an occurrence or evolution of a phenomenon. It can also give a detailed examination and account of a particular context or setting.

By tapping into the fields of cognitive psychology, mechanical engineering, and education, new research can explore the nature of the designer's mental model to answer the question: Does the designer store information as a visual model or as a verbal description?

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Appendix A: Summary of Site Visit to Omaha, NE (ArchiCAD Training)

The training was from Monday 9 to 13 January 2000; I was there from Monday afternoon to Tuesday afternoon. The training began with a general presentation on the tools and methodology of ArchiCAD's object technology for the built environments. After the overview the trainees began their hands-on exploration of ArchiCAD. At the training, I observed the interaction and design communications among the designers and collected data on how they communicate design concepts.

Observation

After listening to the lecture, discussions among designers, and questions asked by the trainees, I summarized what I heard and my observations as follows:

Although many CAD programs have succeeded in enabling designers to design, the entire product design process is still very time consuming and error prone due to the lack of collaboration among designers.

The ability to share information is critical to collaborative design. Designers work together by sharing their concepts and design solutions, their ideas, and knowledge; lack of effective communication can hinder collaborative design.

Visual media are a means to express functions, the relationships between functions, and the hierarchy of these functions. Trainees were excited about the 3D capability of the product.

Data Collection

There are five trainees. Out of the five trainees, one was a CADD draftsman, one was a landscape architect, and three were architects. Most of the trainees were familiar with AutoCAD and MicroStation, but none was knowledgeable about ArchiCAD. The trainees were scheduled to start working on a project enti-

tled "The Recreation Center" on the last day of the training. A survey questionnaire (pretest) was given to them at the beginning of the training and the same questionnaire (post-test) would be given to them after the completion of their design project. Here are the questions and responses:

In selecting basic structural/material systems, what visual media would help you communicate design to a structural engineer?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
3D sketches and models	Model	3D model, sketches, and photos	N/A	3D model

What visual media would you choose to present your design to a landscape architect and a civil engineer to discuss site-planning issues?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
Axonometrics and perspectives	Site model	Plans, photos, and sketches	2D Plan	3D model, plans, and elevations

Which visual media would you use to explain a fire rating to mechanical engineers?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
Diagrams and 2D sketches	Axonometrics	Plan and diagrams	2D plan	Wall sections and floor plans

Which visual media would you use to explain an alarm/security system to electrical engineers?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
Diagrams and 2D sketches	Model	2D and diagrams	2D or sections	Floor plan

What is/are the best visual media to explain a design concept to a customer who is not familiar with architectural conventions?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
3D model	Model, movie or fly through	3D model	3D model	3D model and 2D site plan

What is/are the best visual media to explain a design concept to another architect?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
3D sketches and diagrams	Model	3D model	3D model, plan, and elevations	3D model and floor plan

In what situation would you prefer 2D media to express your design?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
During schematic stage for organizing spaces.	None	Sketching or diagram	To show floor layouts and elevations	When communicating with other designers.

In what situation would you prefer 3D media to express your design?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
Discussing the overall intent of the design development.	Convey ideas to customers	Customer presentation and marketing	Conceptual stage of design	To customers who cannot read floor plans.

In what situation would you prefer tabular media (spreadsheet) to express your design?

Architect 1	Architect 2	Architect 3	CADD Drafter	Landscape Architect
Discussing quantities such as net/gross area.	Door schedule	None	Never	None

What issues in a design communication between architects and engineers would you suggest we address?

Architect 1

The architect is usually less consistent about layering which complicates the engineers. Ability to read the architects electronic drawings. Changes tend to be very frequent at the end of the design phase as well as construction document phase due to budget, program and organizational changes, equipment, or technological changes. Engineers need to coordinate these changes sent from architect.

Architect 2

Need a mechanism to illustrate collisions between structural, mechanical, and architectural. Need a better way to look at furniture arrangements, life safety, and fire codes.

Architect 3

Better hardware and program support. Training is lacking the way we use CADD.

CADD Drafter

None

Landscape Architect

The resistance of mechanical and structural engineers to learn CAD.

The intent of this survey was to compare the pretest with the posttest and see if there is any correlation. Also, this information would help us to design a valuable instrument for our study on Advance Visualization.

Appendix B: Improving Design Communication Survey

We are conducting this study to determine how architects and engineers use visual media to communicate design ideas to their customers and other design team members with the objective being to improve the ability of the Corps to attract and retain customers and improve the design process. In responding to the questions, use the drawings (VIS-2D and VIS-3D) located at ftp:/ftp/cecer.army.mil. Download the 2D and the 3D drawings and use them to answer the following questions. **Please explain the reason for your choice for each question.** Thanks for your participation.

In selecting basic structural systems, which of the visual media would help you communicate design to a structural engineer?

What visual media would you choose to present your design to landscape architects to discuss site-planning issues?

What visual media would you choose to present your design to civil engineers to discuss civil engineering issues?

Which visual media would you use to explain a fire rating to mechanical engineers?

Which visual media would you use to explain an alarm/security system to electrical engineers?

What is/are the best visual media to explain a design concept to a customer who is not familiar with architectural conventions?

What is/are the best visual media to explain a design concept to another architect?

In what situation would you prefer 2D media to express your design?

In what situation would you prefer 3D media to express your design?

In what situation would you prefer tabular media (spreadsheet) to express your design?

What issues in a design communication between architects and engineers would you suggest we address?

Thank you. Please return your completed questionnaire to your trainer at the end of this training. Please provide your name and e-mail address so we can share the result of our study with you in the future.

Name:

E-mail:

Address:

Appendix C: Improving Design Communication, Visualization Study Survey Instrument

Visualization Study
CERL
10 Oct 2000

The U.S. Army Construction Engineering Research Laboratory (CERL) is part of the U.S. Army Engineer Research and Development Center (ERDC), which is the Army Corps of Engineers' integrated research and development organization.

CERL works closely with a variety of organizations, including customers and other ERDC laboratories to improve design process.

To help us better understand design process and improve design communication, we request that you participate in this short survey. Your responses to this survey will help us to determine how to improve design communications.

The results of the survey are confidential. The results will provide insights on the use of visual modes in design communication.

Please answer these questions to the best of your knowledge. Please by respond not later than October 27, 2000.

For general survey information, contact Blessing Adeoye, email: blessing.f.adeoye@erdc.usace.army.mil, phone: 1-800-USA-CERL

For technical assistance, contact Blessing Adeoye, email: blessing.f.adeoye@erdc.usace.army.mil, phone: 1-800-USA-CERL

(*=Required field)

*Name:

Organization Name:

Office Symbol:

*Address:

Phone:

Fax:

*E-mail:

Job Title:

Grade:

*Years of experience.

1. What is/are the best visual media to explain a design concept to a customer who is not familiar with architectural conventions? Please explain the reason for your choice. (check only one)

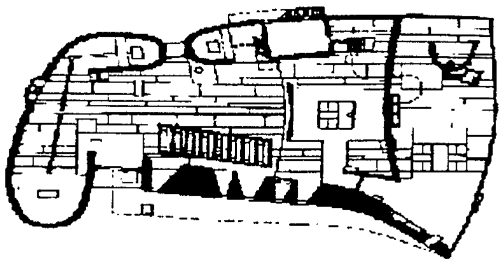
- 2D
- 3D
- Both 2D and 3D
- None of the above

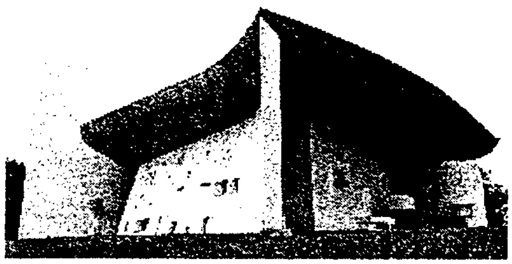
2. What is/are the best visual media to explain a design concept to another architect? Please explain the reason for your choice. (check only one)

- 2D
- 3D
- Both 2D and 3D
- None of the above

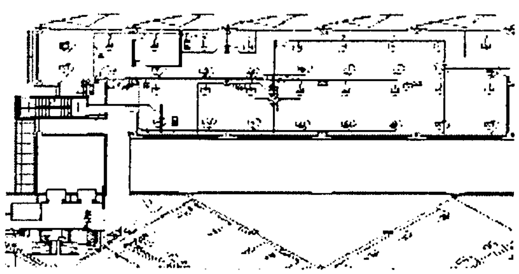
3. In what situation would you prefer 2D media to express your design? Please explain.

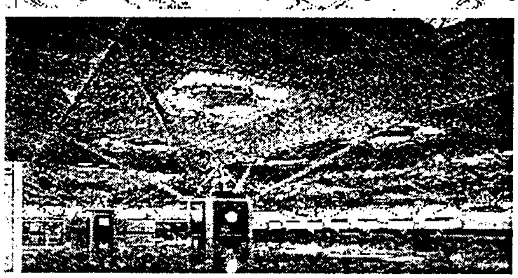
4. If you can only choose one from these two graphics, what visual media would you use to explain a fire rating material to a mechanical engineer? Select from the media below. (check only one)





5. If you can only choose one from these two graphics, which visual media would you use to explain an alarm/security system to electrical engineers? Select from the media below. (check only one)



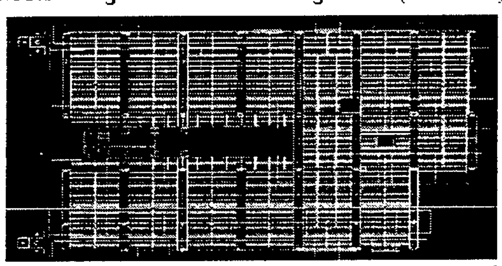


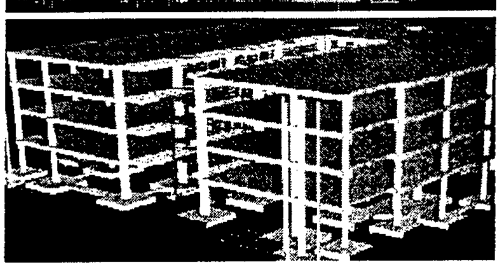
6. What issues in a design communication between architects and engineers would you suggest we address?

7. In what situation would you prefer 3D media to express your design? Please explain.

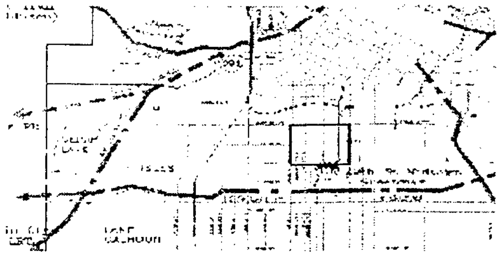
8. In what situation would you prefer tabular media (spreadsheet) to express your design?

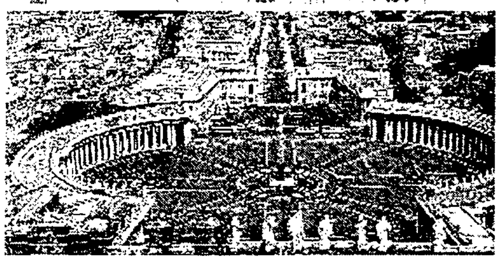
9. In selecting basic structural systems, which of the visual media below would help you communicate design to a structural engineer? (check only one)



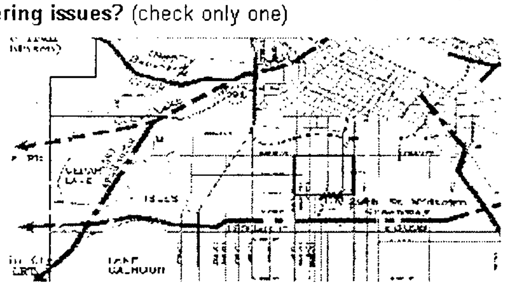


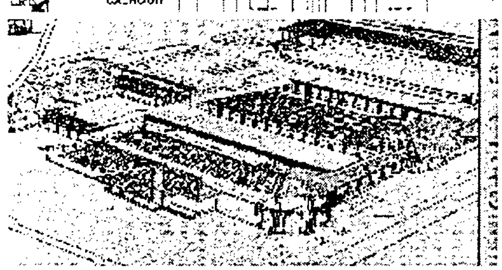
10. What visual media would you choose to present your design to landscape architects to discuss site planning issues? (check only one)





11. What visual media would you choose to present your design to civil engineers to discuss civil engineering issues? (check only one)





12. Please add any additional comments you may have.

Thank you for participating in this study.

Submit Survey

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14. ABSTRACT

Architects work in a multidisciplinary design environment that spans engineering and the construction domains, and they must communicate themselves to colleagues across disciplines. While design professionals may use similar visual modes (lines, text, graphic symbols, etc.) to represent and communicate concepts in complex drawing tasks, similar visual modes may be used ambiguously across disciplines. Consequently, unless there is a standard definition for given graphic elements, a design's audience is likely to interpret the visual modes from its own experience or perspective. This study used an online survey to collect information from Corps designers and architects in private practice to explore ways to improve design communications among designer professionals by determining how architects and engineers use visual media to communicate design ideas with their customers and other design team members.

15. SUBJECT TERMS

visualization	design communication	visual media
design automation	architects and engineers	

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